THE GEOLOGIC DAY

ALFRED C. LANE
Lansing, Mich.

The fact that geologic formations, whether lithologic or faunal units, given the same name—the Potsdam, for instance—are not in all parts strictly contemporaneous, has been often noted. Terms like "homotaxial" have been applied to them to avoid the assumption of contemporaneity.

A good part of the time of the geological congresses has been devoted to a discussion of problems of a similar nature. Yet it is rarely, if ever, noted that the same problem comes up in connection with the civil day, and, in fact, with any possible measurement of time.

It has just been vigorously impressed (April 19) that 5:13 San Francisco time is not the same as Washington time, but about three hours later. Therefore the day ends and begins later at San Francisco than at Washington. The sidereal day is a little different from the solar day, the astronomical year from the civil year. The reason for this lies near to the heart of things. Time is measured by change, and change, as we know it, must progress from point to point. The progress may be as rapid as an explosion or as the transmission of light, or as slow as the precession of the equinoxes. Nevertheless, there is always a rate of progress which is measurable, and any interval of time must be marked by a certain stage in the change, and so begin differently at different points.

There is no reason to be surprised, therefore, if we find this to be true in dividing up our geological time. We measure it generally by some slow change: the evolution of life, or orogenic movements, or the accumulation of salt in the sea, the changes in sedimentation consequent on elevations of continents, or changes in climate, like the passing away of the glacial epoch.

Take postglacial time for an illustration. It is clear that the ice must have retired from the valley of the Ohio before it retired from

the Straits of Mackinac some time, and perhaps a very long time. Therefore the postglacial epoch begins later at Mackinac than at Cincinnati. Yet I do not think that it necessarily should have a different name, any more than April 18 has a different name for Europe and America. Of course, there are difficulties, just as there are difficulties in saying what is the birthday of a child born near midnight, or near the date-line in the Pacific. But they are inherent in the facts, and are not lessened by introducing new terms, which indeed may lead one to overlook the realities of the case. All these difficulties as to exact time, however, real as (for instance, to friends of the Psychical Research Society, discussing apparitions of the dying) they are at times, form but a fraction of the total application of the usual terms, "day," "year," and "hour," which are ordinarily intelligible and unambiguous. Is it not so with the geologic terms, and may we not ordinarily be justified in speaking of our Eastern and Western Niagaran by the same name as belonging to the same geologic year and coeval, even though we know one lithologic unit may have begun to form somewhat sooner than the other?

Difficulties have arisen from the fact that the lithological evidences of contemporaneity do not always agree with that furnished by fossils, and the early assumption (really a relic of the old cataclysmic theory, according to which God made one set of created beings, then wiped off his slate and began over again) was that fossils were the best and surest index of contemporaneity, in comparison with which all other factors or means of determination were of no weight.

No competent paleontologist now holds this extreme view, and many of them, like Williams, have shown clearly that fossils are not absolutely inerrant evidence of contemporaneity. Yet the influence of the old views, and the idea that the lines of a division of geological time must be lines separating different faunas, has so clung on that the tendency has naturally been, where the faunas proved misleading, to give up the idea of time entirely, and refer merely to homotaxis.

This will be a mistake. The idea of time is present in our geological divisions and their names, and though our divisions be imperfect expressions of our ideal, for that reason to throw away the ideal would be to make the same mistake as Hobbes, to whom a straight

line was merely the straightest line he could draw, and who accordingly thought he had squared the circle, because he found a construction which was correct so far as he could see. It does not follow, however, that we should give a new name every time we find evidence of real difference in geologic time in the beginning of one of our geologic divisions. It should be carefully noted, and left to be weighed and compared with other evidences, until we are ultimately able to place each division at each place accurately on a true scale of time, which shall be to the common scale as is astronomer's time to the local times and seasons of everyday use.

Of these various evidences, fossils are by no means the best evidence of strict contemporaneity. Other evidences, as good or better, are:

1. A shower of volcanic ash like that which has recently come from Vesuvius, *if* it can be identified, is one of the best evidences of contemporaneity. The same remark applies to a surface lava flow. Individual lava flows of peculiar character, like the foot of the Kearsarge lode, have been traced many miles in the Keweenawan, and great floods out West may, I presume, be equally contemporaneous. In time to come, geologists of the future may use volcanic ash-beds, among the series of shales and muds, which are overlooked now, as horizon-markers of the first importance.

2. The whole nexus of mud-flows, lavas, ash-beds, and the like, which make up an eruptive epoch, would not make so exact an index of contemporaneity, but in many cases are of considerable value. The Keweenawan, and Triassic of the Atlantic coasts are illustrations both of the value and of the danger of such correlations. While indicating real contemporaneity, if the correlation is correctly made, there is likely to be an eruption of indistinguishable rocks (or nearly so) at widely different times.

The error is analogous to that which may be made by confusing colonies among fossils; though, on the whole, with a large enough fauna there is little danger of faunal confusion.

3. A change of climate may extend with great rapidity over a province or over a very large part of the world. The glacial period in Europe and America is one glaring illustration. Another is the change in the Carboniferous from the hot, dry climate of the Mis-

sissippian to that of the Pennsylvanian. The change may, of course, have occupied considerable time in its spread, but probably only a fraction of the duration of each period. Salt beds, whether formed in desert wastes or inlets of the ocean, point to a dry climate.

4. If one could only get samples of water in which the strata were buried which had not changed in the meantime, one might, in the case of open marine strata, be able to date them from the progressive change in the character of the sea water. This may be of more value in the future than in the past, as it probably can be used only on water carefully preserved from deep borings in slightly disturbed synclinals where numerous beds are impervious.

5. Changes in the elevation of the land, and consequently in the shore-line, produce changes in the sedimentation in which climate may co-operate. These changes in the sediment-determining factors may be slow, like the tilting of the basin of the Great Lakes, now going on. But even in such cases they may be nearly simultaneous over long stretches of shore-line. They may also be sudden, like the uplifts of the South American coast described by Darwin and numerous other earthquake disturbances. In general, it may be said to be likely that a sudden change, involving the injection of fine mud in the ocean water, is not likely to be extremely local.

As a result of these changes, the fauna is driven hither and thither, and more or less modified by the stress of circumstance.

If the difference in sedimentation slowly progresses, it is quite possible that the corresponding change of fauna will be equally slow in spreading from point to point. Thus, in determining what is really genuinely coeval, there is often no reason to prefer the evidence of fossils to that of sedimentation, if all the factors of the early geography are duly taken into account.

The great advantage that the fossils have is that they never come back to their original combinations. The course of life has never really gone backward, whereas sandstones, limestones, and shales of recent times may be undistinguishable from those of earlier times. Thus, when it comes to determining the general place in the geological column, to deciding whether the Lake Superior sandstone was "New Red," "Old Red" or coeval with the Cambrian, fossils, if obtainable in sufficient quantity, far outclass other kinds of evidence.

But when it comes to minute comparison, they are by no means exclusively to be trusted. If we find ourselves following along the shore-line of an older, settling land-mass, and there are indications that the land settled as a whole without tilting, or that, if it tilted, we are still following one coeval shore-line, which was the farthest extent of the overlap of the time, we may often be sure of a good degree of contemporaneity, independent of fossils. Of course, if we regard black shales as colored by pollen and spores, it may be said that the black shale is a faunal characteristic. But if we disregard the species and genera of spores, it becomes a mere physical characteristic, dependent on climate, like a bed of salt. Then we may fairly ask if the physical change which leads to the sudden appearance of a bed of black shale above a limestone (like the Marcellus above the Corniferous) is not likely to be closely contemporaneous over a wide area. We may extend such illustrations indefinitely. The point that I would make is that, while the paleontologist can sometimes draw fine lines of time-division, a careful stratigrapher, a paleogeographer, can at times draw equally valuable lines of time-division, as nearly the same in different places, relatively to the lengths of the intervals separated, as the divisions of civil time.

If objection is made to using paleontology for the larger and broader time-determinations, and using various other methods for details, and not always drawing the line at the same place in using terms applied to these divisions in the different regions, we can again fall back on the analogy with the divisions of common time, where the sun rules the year, and the moon long ruled the month, while the finer and more exact divisions depend on other data, and the year does not begin or end exactly at the same time at every place.